DOCUMENT RESUME

ED 194 356 SE 033 206

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TITLE Energy Conservation Guidelines - 2: Energy Conservation in School Facilities.
INSTITUTION New Jersey State Dept. of Education, Trenton. Bureau of Facility Planning.
PUB DATE 80
NOTE 21p.; For related documents, see SE 033 205-208.
AVAILABLE FROM Office of Central Services, Div. of Administration, New Jersey State Dept. of Education, 225 West State St., Trenton, NJ 08625 ($1.50).

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Building Systems; *Cost Effectiveness; Educational Administration; *Educational Facilities; Energy; *Energy Conservation; Money Management; *Utilities
IDENTIFIERS Energy Consumption; *Energy Management

ABSTRACT

The suggestions contained in this guide are intended to help reduce energy consumption in school facilities. Energy conservation measures are discussed on three levels: (1) the educational program and activities schedule, (2) operation of the facility and supporting systems, and (3) the physical plant. Discussed are high cost, medium cost, and low or no cost energy management strategies. (WB)

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ENERGY CONSERVATION GUIDELINES

2 Energy Conservation in School Facilities

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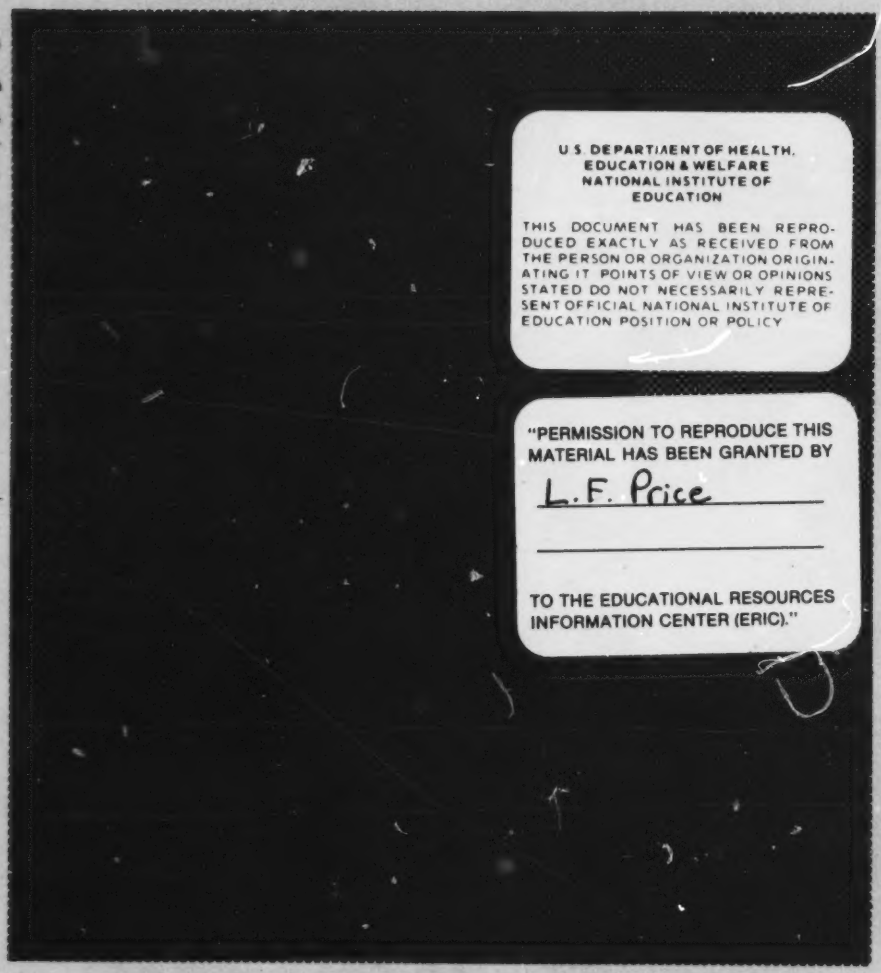

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ENERGY CONSERVATION IN SCHOOL FACILITIES

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Commissioner of Education

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225 W. State St., Trenton, N.J.
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Fall, 1980

PTM no. 100.23

FOREWORD

Over the past six and one-half years the Department of Education has sent out memos and published in *interact* numerous recommendations for making school facilities more energy efficient. The amount of energy being consumed in schools has decreased as a result. (According to a study conducted in 1975 by the Federal Energy Administration, consumption went down 15 percent in the first two years of the energy crisis; as a result of the diligent efforts of all school related personnel, we believe energy consumption has gone down even further.)

Since 1975, energy usage in schools has decreased considerably; however, there is still room for improvement. Energy "conservation" is often referred to as energy "cost savings" because as we make more efficient use of energy in schools and thereby reduce or eliminate waste there will be a considerable amount of money saved, money which will then be freed for use in other budget accounts. Not to take advantage of every opportunity for improving energy use efficiency in schools could be labeled "waste" by the public. A news article a year ago stated that "The nation's public schools will waste $740 million on energy this year." This figure was based on the findings of an earlier study which showed that "most schools could reduce their energy consumption between 20 percent and 30 percent by implementing low cost conservation measures and that another 20 percent reduction would be possible through building modifications." If we apply these findings to the amount of money being spent annually in New Jersey's public schools for heating, cooling, and lighting purposes and escalate these costs for the coming year, we could estimate that **New Jersey public schools will "waste" close to $140 million in energy this year.**

It is interesting to contemplate what this money could do for educational programs if freed for that purpose. Many districts have gone as far as possible with operational and administrative changes to conserve energy; this bulletin should provide ideas on additional energy-saving measures. In the accompanying recommendations we have attempted to be more specific regarding energy management and facilities related energy saving measures. If you have questions regarding any of these items do not hesitate to call Mr. Richard Gates, Architectural Supervisor, Bureau of Facility Planning Services (609-292-4412).

It would also be in a school district's best interest to participate in the current federal energy program of financial and technical assistance under the National Energy Act. This requires having a qualified local person or a consultant conduct a preliminary energy audit of each school building. The audit is reviewed by the Center for Technology Assessment at the New Jersey Institute of Technology and a report made to the district on potential energy savings. A preliminary audit is essential if a district is to receive technical assistance, detailed engineering analysis and financial assistance for physical changes to a building. For more information about this program, contact Mr. F. Monachello at the New Jersey Department of Energy (201-648-3901).

In this bulletin an educational facility is viewed as a system composed of plant, students and teachers, materials, support staff and program. Three levels will be considered at which energy-saving strategies can be developed and implemented:

1. **Program**—the educational program and schedule of activities taking place at the school.
2. **Operation**—how the facility and its supporting systems are run to house and support these educational activities.
3. **Physical plant and its operating system.**

In general, program and operation changes only modify the way an existing facility is used and, therefore, usually entail little or no expenditure. On the other hand, changes to the physical plant or to one or more of its operating systems may be quite expensive. Practical energy-saving strategies at each of the three levels are discussed in the following sections.

Irving M. Peterson, Director
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PROGRAM MODIFICATIONS

The educational program and schedule of daily activities are normally considered a stable factor around which all other elements in the school system revolve. The school's program reflects its primary function, the encouragement of learning and the sharing of knowledge. Most programs and schedules, however, have some room for trade-offs which can result in energy savings.

One such trade-off is the proper use of a plant at night or on weekends when it is less than fully occupied. If activities during these times are scheduled in such a way that all the spaces used are in a single heating or cooling zone, or are at least adjacent, the remainder of the plant can be shut down and the minimum of energy used.

The effect of program changes on energy consumption was shown by a study in Colorado. Using a computer simulation package, the study discovered the following energy variations resulting from variations in scheduling:

- Shutting down the school completely during Christmas vacation *and* the month of January could result in an annual heating fuel savings of 23.9 percent.
- Extending Christmas vacation another week could result in heating fuel savings of 5.8 percent per year.
- Starting school as late as 11:00 a.m. in the winter and running later in the afternoon would save only about five percent of the heating fuel per year.
- Using the school on a year-round basis, requiring air-conditioning in the summer months, would add 61.2 percent to the annual fuel and electricity bill.
- By turning heat on at 7:00 a.m. and off at 3:00 p.m. (on school days) actual fuel consumption could be reduced by 13.8 percent annually.

Another scheduling technique that encourages energy conservation involved programming space use so as to place visual tasks in areas of specially designed lighting. This procedure can save considerable electrical energy by allowing a reduction in the general lighting level. In addition, visual tasks themselves may be modified. For example, the reading of #2 pencil on manila paper requires about 50 times as much light as reading felt-tip pens on matte white paper.

OPERATION MODIFICATIONS

Cutting Waste in Lighting

There are three ways to reduce a school plant's waste lighting energy; these may be used separately or in concert. They are: (1) reduce the number of lamps; (2) turn off the lamps in unoccupied spaces; and (3) make use of natural lighting when available.

1. **Reducing the number of lamps:** Lighting wattage in existing buildings may be reduced either by removing a percentage of fluorescent tubes or by replacing incandescent lamps with bulbs of lower wattage. (Table I shows the annual costs of maintaining various lighting levels.) If this approach is used, reductions in teaching space lighting levels should be based upon state minimum standards – N.J.A.C. 6:22-4.11

Programs of this sort have been implemented in school districts all over the country. The facility director of an eastern district reported that since voluntary light use reduction efforts rapidly lose their fervor, the only way he can achieve his desired savings is by removing tubes. The director of an energy conservation program in a West Coast district reported that when he replaced 500 watt incandescent bulbs in classrooms with 350 watt bulbs over a weekend, space users never noticed the difference.

TABLE 1
COMPARATIVE ANNUAL ELECTRICAL CONSUMPTION AND COSTS FOR VARIOUS LIGHTING LEVELS

(28,000 square foot plant, $0.25 per KWH)

Average Light Intensity	School Plant Used 9 Months Per Year	School Plant Used 12 Months Per Year
30 footcandles	37,750 KWH ($ 3,020)	52,100 KWH ($ 4,168)
50 footcandles	64,200 KWH ($ 5,136)	88,500 KWH ($ 7,080)
70 footcandles	85,600 KWH ($ 6,848)	118,500 KWH ($ 9,480)
100 footcandles	128,600 KWH ($10,288)	177,500 KWH ($14,200)

2. **Voluntary light turn-off programs:** The failure of Americans to turn off lights in rooms they leave is so notorious that a few years ago an American president was the butt of humor because of his attention to this detail. Few school buildings achieve more than 75 to 85 percent space utilization, and if lights were conscientiously turned off in vacant spaces, up to one-quarter of the electrical bill could be saved with *no change* in lighting levels.

Many school districts and institutions of higher education have begun programs to encourage their faculties and students to turn off unused lights and other equipment. Unfortunately, the success of these programs seems to fluctuate, in an inverse relationship, with the availability of gasoline.

Another approach, somewhat more consistent in its results, is to appoint student or staff monitors with responsibility for turning off lights when a room is empty and to periodically check the rooms in the plant for use.

3. **Use natural light if you have it.** If a building receives natural light through windows and skylights, the use of artificial lighting in the rooms should be adjusted accordingly. Some school plants have separate switching circuits for banks of lights near the windows, a useful idea which could be added to all school plants with large window areas and, if properly used, could result in considerable energy savings. A study indicates that each linear foot of properly designed window (measured along the sill) can save up to 100 kilowatt-hours per year.

Cutting Waste in Heating and Cooling

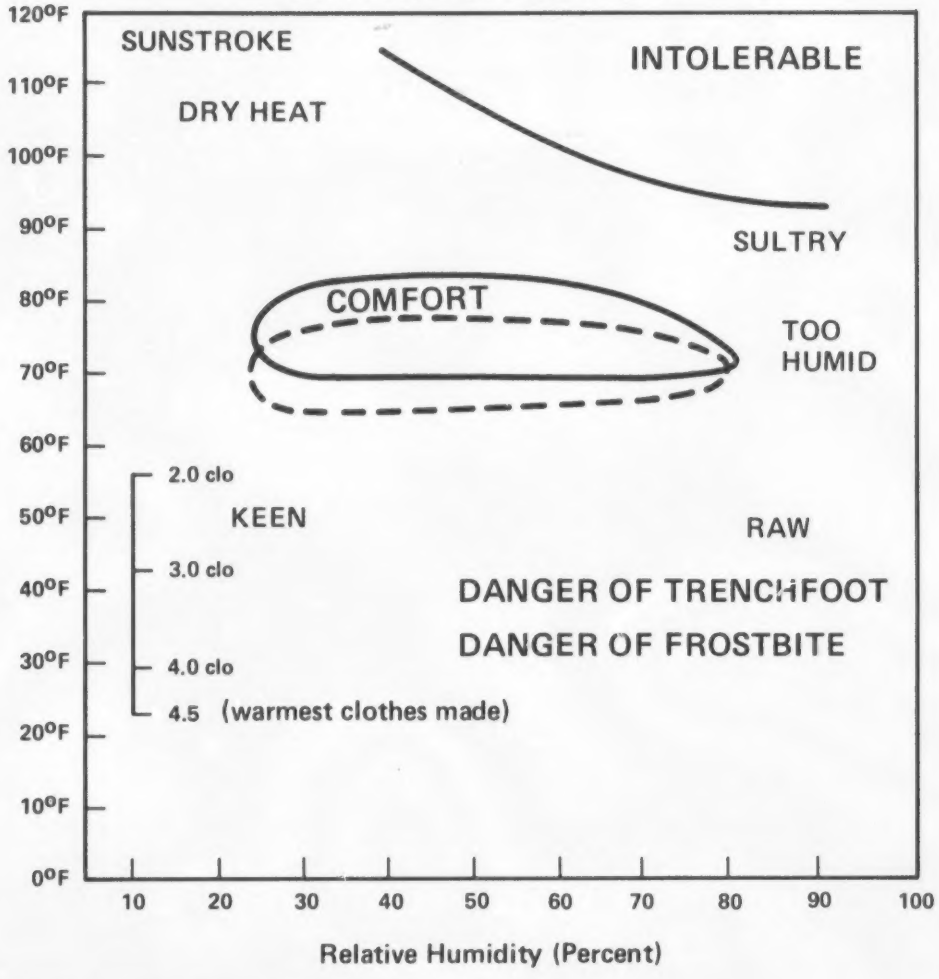
The maintenance of a healthful and comfortable interior environment requires that the temperature and humidity be maintained within the "comfort zone" of conditions illustrated in Figure I. Although conditions are often expressed as a single set of figures (such as 75°F, 50 percent relative humidity), an examination of Figure I shows that comfort conditions are actually a range of values, slightly different for summer and for winter and for different activity levels.

In an existing plant, maintenance of these desired conditions can be assured (with minimum energy consumption) by taking three steps: (1) setting the thermostats lower in winter and higher in summer; (2) reducing and controlling the amount of outside air taken in; and (3) using appropriate setbacks when the plant is not occupied.

1. **Change thermostat settings:** A study sponsored by the Colorado Department of Education found that reducing the thermostat setting for room temperature in classrooms from 75°F to 68°F in winter could save an estimated 23.4 percent of the annual heating fuel consumption. From an examination of the comfort zone in Figure I, the reader can see that a setting of 68°F is still within the range of comfort, provided the humidity level is not too high. Spaces in which more rigorous activities take place can be further reduced in temperature; in fact, such

FIGURE I

Human Comfort Zone



SOURCE: Victor Olgyay, *Design with Climate*, pp. 19-24.

reductions are beneficial to the person engaged in these activities. The following figures were given by the New York State Education Department's "Energy Usage Guidelines" for adequate temperatures in various spaces:

Classrooms	68°F
Shops	63-65°F
Gymnasiums	63-64°F
Storage and other non-student spaces	50-55°F

Since wearing warm clothing, especially clothing that covers arms and ankles, increases comfort at lower temperatures, schools should recommend warm apparel in winter and cool apparel in summer.

2. **Control outside air intake:** Outdoor air is introduced into a building in two ways—intentionally, for the purposes of ventilation and air freshening, and unintentionally, through flaws in the building fabric and by opening and closing doors and windows. Whenever outside air is introduced into the building, it must be treated—heated or cooled—to match the conditions of the air in spaces of the building. **Up to one-half of the total heating and cooling bill may come from this treatment of intentional and/or accidental outside air intake.**

Controlling outside air introduction so that only as much air as is required is brought into the building is one major energy savings in school plants. In buildings with mechanical ventilation, this control includes sealing of the plant against accidental introduction of outside air, or *"infiltration,"* checking the settings of outside air intake dampers to insure that only the desired amount of air is actually being introduced, and shutting off the outside air fans when the plant is not occupied. Research indicates that the operation of intake and exhaust fans during unoccupied hours is also a major cause of energy waste.

An energy study, undertaken in Fairfax County, Virginia, estimated that in buildings relying upon intake and exhaust fans, a reduction of 50 percent in the outside air intake is possible. This reduction, which still puts ventilation rates above the minimum requirements, would result in annual energy savings of about 25 percent **with no investment.**

Control of outside air introduction in buildings relying on natural or gravity ventilation is more difficult to achieve but appropriate action, such as weatherstripping windows and sealing cracks, can still result in energy savings. Fairfax County computer simulations put these savings at about 35 percent if the level of outside air introduction can be held to recommended levels.

3. **Setback the system:** Appropriate setback of the mechanical system during unoccupied periods is another source of energy savings which offers big results for little cost. Although most buildings built in the last three decades are equipped with setback controls, experience indicates that as many as one in three of these units may not be effective because of malfunction and a larger proportion because of improper use. This is to remind the reader that even if an energy-saving device is provided, a certain amount of supervision is necessary to ensure that it is used and used properly.

In setback, the load on the mechanical system is reduced by allowing the inside temperature of the building during unoccupied hours to fall in the winter and to rise in the summer – in mild climates, the system may be completely turned off during these times. Thermostats should allow a heating setback to at least 55°F.

Proper System Maintenance

It is a truism that well-maintained systems can operate efficiently. In spite of this fact, however, one energy expert has estimated that as many as 80 percent of school building mechanical systems operate improperly due to poor or nonexistent maintenance.

Part of this problem results from the absence of appropriate training programs for custodial, maintenance and supervisory personnel. Two notable efforts to alter this situation are as follows: The Division of Engineering of the North Carolina Department of Education uses an extensive and successful program of workshops and video tapes to teach plant custodians and maintenance personnel proper maintenance and operations of their buildings. This program includes such energy-related topics as testing burner efficiency and manual shifting of electrical load to reduce peak demand.

The second program was developed as part of a community college curriculum by the Portland (Oregon) General Electric Corporation (PGE) in cooperation with a community college and several area school districts. In this program, the community colleges offer regular courses for custodians and maintenance personnel with full credit available. PGE provides materials and instructors for the program.

PHYSICAL PLANT MODIFICATIONS

Assuming that a plant is operating relatively efficiently, that is, with little or no waste of energy, it may be necessary to invest funds in the plant in order to achieve further energy savings. An effective analysis of energy-saving strategies which require investment cannot be made without some form of life-cycle cost analysis.

Mechanical Systems

Wearing out of the system or of its components or the preparation of a cost/benefit analysis may indicate the advantage of replacing all or part of the mechanical system in an existing plant with one which has better energy consumption characteristics. For example, providing a separate water heater or a smaller supplementary boiler may result in fuel savings in mild climates. It may also be found that existing mechanical plants have surplus capacity which may be used for additions, other plants or other uses.

Several manufacturers now produce systems, designed to be placed into existing plants, which provide efficient heating, ventilating and/or cooling while making extensive use of salvageable portions of the plant's existing systems.

In plants with central systems, the use of a heat recovery device between the outdoor air intake and exhaust air streams should be considered. An estimate made for the Fairfax County energy study indicated that at the two secondary schools to which this technique was applicable, such devices would pay for themselves in 5.9 and 6.8 years respectively. Heat can also be recovered from light fixtures and persons using a space. Heat has also been taken from neighboring industrial and utility company reservoirs which contained water which has been warmed in the manufacturing or electric generating process.

Improved control systems can be fitted to most existing plants at moderate expense and can greatly reduce consumption and costs. Time-sharing computer control of building systems is also available in some locales.

Lighting Systems

Upgrading the lighting system is a common element of most modernization programs. When such upgrading is done, the designer should be careful to select the most efficient type of lighting source and to design it for low general levels with higher levels only where needed. The higher the ratio of lighting output per watt of input power, the lower will be the energy consumption to achieve any desired level of lighting—Table II lists some available high output lighting systems.

Switching patterns for lighting should allow for use of daylight and for some flexibility of use. The exterior banks of lights in rooms should be switched either manually or automatically, by photoelectric cells, to permit turning lights off when adequate natural light is available. Two-level switching may be provided but teachers must be instructed in its use, to allow varying light levels in the classroom to respond to different educational activities.

TABLE II

EFFICIENCIES OF VARIOUS LAMP TYPES

Fluorescent lamps provide three times the lumens per watt of a standard incandescent (filament) lamp.

Fluorescent lamps lose efficiency at their ends. Efficiency is gained by the use of fewer and longer tubes:

2 – 24 inch cool white lamps = 50 lumens per watt
2 – 48 inch cool white lamps = 70 lumens per watt
2 – 96 inch (800 MA) lamps = 73 lumens per watt

High Intensity Discharge (HID) lamps:

400 watt metal halide lamp = 75 lumens per watt
1000 watt metal halide lamp = 85 lumens per watt

SOURCE: Charles D. Gibson, "Energy Saving Efforts Related to Lighting" (paper read to Southwest Regional Conference of the Council of Educational Facility Planners, International, Sacramento, California, April 20,1974).

ENERGY COST SAVING MEASURES

Low Cost or No Cost

Heating

- Clean furnace burners regularly. Cleaning boilers regularly provides maximum heat transfer and lengthens the life of the boiler. (A 1/8 inch layer of soot or scale can add eight percent to fuel consumption.)

- Check steam traps regularly for leaks. (In one day the cost of lost steam can be greater than the cost of the trap itself.)

- Weatherstrip windows and seal cracks in buildings, including attic space. Weatherstrip and caulk all doors and windows.

- Install a seven-day clock for night set-backs and to control heating hours. (The clock turns the furnace on and off at predetermined hours. For example, a minimum of 55°F may be maintained throughout a building during off hours. Also, by adding or removing control pins, the clock will control the furnace for holidays or weekends.)

- Reduce the number of heating hours each day – turn heat on at 7 a.m. and off again at 3 p.m. each school day.

- Keep heat in rooms in winter by keeping classroom and exterior doors closed (manually or with automatic stops) and keep classroom windows closed.

- Clean each school building in daylight hours whenever possible. (At night, use lights only as needed. Instruct custodians to turn off lights and H.V.A.C. in local areas as they finish their work.)

- Reduce or eliminate evening school and night football games as much as possible. (If night games are essential use only one bank of lights during pregame and halftime shows.)

- Operate unit ventilators in accordance with the manufacturer's specifications. Reduce air intake by 50 percent or more.

- Modify operation procedures, where necessary, to heat only space which is in use, reduce heating levels during off hours, reduce temperature of service and washroom hot water, heat water during off hours and store for later use, reduce ventilation air and recycle air for heating and ventilation to the maximum extent, clean and replace air filters regularly, and insulate walls, ceilings and roof.

- Repair and maintain temperature controls and night setback controls. (Contract to have all thermostats calibrated regularly to prevent overheating in rooms.)

- Shut off all exhaust fans between 3 p.m. and 7 a.m. during winter months.

- Lower thermostat settings for heating, and raise settings for cooling, (It is most important to keep temperatures from getting too high to where automatic cooling ventilators get turned on in winter.)

- Lock thermostats to avoid arbitrary adjustments which can throw the entire system out of balance causing the heating and cooling systems to work against each other.

- Lower thermostats at night in the winter to 55°F for at least eight hours. A clock thermostat should be installed for this purpose.

Air Conditioning

- Clean filters in air conditioning units to keep fan power at its maximum.

- Clean and service air conditioners regularly. (In general for every $1.00 spent on maintaining air conditioning equipment, $6.00 is saved in operating costs).

- Place decals in air conditioned rooms to remind people to keep doors and windows closed.

- Do not set thermostats lower than 78°F during the cooling cycle.

- Use outside air when air temperature is below 78°F.

Lighting

- Turn off lights when not needed for 15-30 minutes. Place decals over light switches to remind people. A sample decal might read, "If you are leaving this room, switch the light off."

- Use natural light whenever possible.

- Reduce lighting (illumination) levels to state minimum standards in all areas where lighting is excessive. If a school is used 75 percent of a school day (on the average) then 25 percent of the room will be vacant at any given time and lights in these rooms should be turned off.

- Turn all lights off after 6 p.m. fluorescent lights turned on from 8 a.m. to 6 p.m. five days each week last almost three times as long as those left on for 24 hours a day all week.

- Install time clocks for lights in areas difficult to reach.

- Install photocell controls on outdoor lighting.

- Replace fluorescent lamps after 80 percent of their life expectancy. More energy is used and less light produced during the last 20 percent of their lives.

Medium Cost

Heating

- Add insulation to outside walls and roof. Payback, in reduced heat costs, is 2-5 years. It also reduces heating equipment capacity requirements so that when a boiler is replaced it can be smaller.

- Reduce each oil burner nozzle size; most existing school burners are oversize.

- Insulate all steam and hot water pipes and hot water tanks.

- Fine-tune each oil burner (using a kit at a cost of approximately $300). The kit measures, among other things, the amount of carbon dioxide, smoke and draft being emitted by the furnace. Adjustments are then made to reduce excessive draft and smoke, and increase carbon dioxide output (a carbon dioxide level of nine percent is considered good; levels over 11 percent are excellent).

- Reduce glass areas, by 60-80 percent in rooms with excessive glass area and by 17-35 percent overall, using a porcelain-over-hardboard panel with a one-inch urethane insulation.

- Drop high ceilings to the 9'-6" average presently in state standards. Dropping the ceiling not only reduces the room's air volume that must be heated and cooled, but also creates a good insulation from the roof floor levels.

- Refit (using a kit) all water heater insulation. The payback is 15 months for electric heaters and three and one half years for gas water heaters.

Lighting

- Replace incandescent lights with fluorescent (except in wash rooms, closets, etc. where little light is needed and in high ceiling areas for ease in bulb replacement).

- Provide separate light switches for room areas closest to windows so that those lights can be turned off when natural lighting in that area is sufficient.

- Divide corridor lighting into zones to allow half of the lights to be turned off at times.

High Cost

Heating

- Install a heat recovery device between the outdoor air intake and the exhaust. A heat recovery system may also include the circulation of air through the luminaires. (Luminaires should be cleaned regularly and one-third of the lamps replaced annually.) "Waste" heat (75 percent of excess heat from lights and humans) can be reclaimed through light fixtures into the ceiling plenums.

- Replace inefficient oil burners with new, higher efficiency burners having a reduced firing rate.

- Install heat exchangers to recover normally wasted exhaust heat. Water heat pumps are two and one half to six and a quarter times more efficient than normal electrical heating methods.

- Convert packaged units to central HVAC.

- Install energy storing systems and reclaim stack heat for hot water.

- Install double glazing on window areas (which remain after a reduction is made in the overall window space).

Most of the above recommendations will result in lower fuel bills in winter, and a number of the recommendations also have applications in the summer season, to reduce fuel bills during the cooling cycle. To encourage continual efficiency in energy usage, monthly and yearly energy savings should be displayed in each school building in a prominent place for all to see.

A school's first priority must be towards a greater efficiency in the operation of the heating, air conditioning and lighting systems. It is necessary to continually monitor boilers, controls relating to infiltration, hours of operation, prime energy movers (such as motors and pumps), windows and temperatures in each school building. Most schools can reduce their energy consumption up to 25 percent with no capital modifications by simply changing their methods of operation. When capital modifications are made, savings can reach 60 percent in many existing school buildings.

SUMMARY

In this booklet, a number of techniques for conserving energy in existing plants have been introduced. An effort has been made to view the school as a system composed of a number of elements—plant, users, program, schedule—and to show how energy may be saved with each of these elements.

A great deal of energy can be saved, with little or no cost by looking at the energy that plants are actually using and reducing excessive and unnecessary operations and activities. Squeezing out this waste can result in annual cost savings which are substantial. Modifications requiring investment can and will produce further energy and cost savings if wisely made. Life-cost analysis can help direct these investments.

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